EXTANT AND FOSSIL SPONGIOFAUNA FROM THE UNDERWATER ACADEMICIAN RIDGE OF LAKE BAIKAL (SE SIBIRIA)

E. WEINBERG, C. ECKERT, D. MEHL, J. MUELLER, Y. MASUDA AND S. EFREMOVA

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Sediments of Lake Baikal contain unique and highly diverse siliceous assemblages. Sponge spicules and diatom frustules are both well preserved and abundant. A bottom sediment core STX3GC (4.8m long) was taken from the Academician Ridge using a gravity corer and studied at intervals of 10cm. At discrete intervals sediments consisted of 10-30% by weight of biogenic silica. Major contributors were diatoms, which are a good tool for stratigraphic assignments. Sponges were also widely distributed in space and time, and may also be valuable stratigraphic markers in Lake Baikal, in addition to their important ecological role. Analysis of core STX3GC revealed 4 genera of Lubomirskidae consisting of 9 species, together with scattered mega- and microscleres of *Spongilla* sp. and *Ephydatia* sp. (Spongillidae). Spicule abundance and diversity were highest during periods of warm climate, whereas during cold intervals *Spongilla* sp. and *Swartschewskia papyracea* spicules were missing, and abundance and diversity of other spicules also significantly decreased. These observed morphometric changes may be applied in tracing palaeoecological and climatic changes in Lake Baikal during the Holocene and Pleistocene, or even earlier, and spicules of new species may hold information on the evolution of Lubomirskidae and their probable spongillid roots. ☐ *Porifera, Lubomirskiidae, Spongillidae, freshwater sponges, spicules in sediments, palaeolimnology, Lake Baikal, Pleistocene, Holocene.*

Elena Weinberg (email: info@lin.irk.ru), Limnological Institute Irkutsk, Siberian Branch of RAS, Ulan-Batorkaya str. 3, 664033 Irkutsk, Russia; Johannes Mueller & Carsten Eckert, Alfred Wegener Institute for Polar and Marine Research, RD Potsdam, Telegrafenberg A43, 14473 Potsdam, Germany; Dorte Mehl-Janussen, Freie Universität Berlin, Institute of Paleontology, Malteserstr. 74-100, Haus D 12249 Berlin, Germany; Yoshiki Masuda, Kawasaki Medical School, Department of Biology, Kurashiki City Okayama 701-01, Japan; Sofia Efremova, Biological Institute, St Petersburg State University, Oranienbaumskoye sch. 2, 198904 St Petersburg, Russia; 21 January 1999.

Compared to most existing fresh water lakes Lake Baikal has many unique features, one of which is its sedimentary fossil fauna. Spicules of siliceous sponges and diatom frustules are well preserved and abundant in sediments. In the Academician Ridge region the biogenic silica content of sediments reaches 10-30% by weight, the main part consisting of diatoms which are traditionally used in palaeostratigraphic analyses. According to Martinson (1936b) sponge spicules in deeper parts of Lake Baikal are of allochthoneous origin because, in his opinion, freshwater sponges live on hard substrata in shallow waters. However, the sedimentary bed of the Academician Ridge represents a silt layer 1,000-1,500m thick, and the water column height above it is 300m. The present work was undertaken to find how sponge spicules have come into the Academician Ridge sediments — if they are autochtonous elements of sediments or have come in from other parts of the lake.

MATERIAL AND METHODS

SAMPLE COLLECTION. Living sponges were sampled between 1996-1997 from the Academician Ridge by dragging the lake bed using a deep water trawler, in a transect extending from the north part of Olchon Island to the south part of Great Ushkany Island. 38 specimens of sponges were collected using this method, with an additional 50 specimens collected by divers from the litoral zone of Great Ushkany I.

Sediment samples were collected by box corers and a gravity corer on board the RV Vereshagin, a scientific research vessel from the Limnological Institute, Irkutsk. Altogether 9 surface samples and a gravity core with a length of 480cm were sampled (see Fig. 5). Sampling was undertaken at

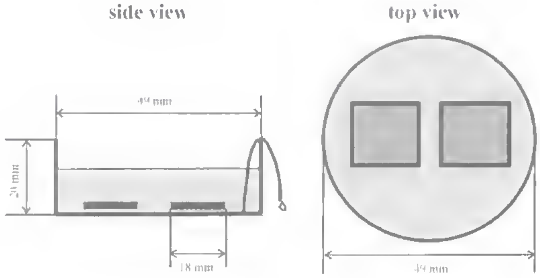

FIG. 1. Schematic illustrations of Petri dish with cover glases for sample sedimentation.

every 10cm interval of the gravity core, i.e. 48 samples for the entire core.

SAMPLE PREPARATION. 5g of each sediment sample was freeze dried for 12hrs, oxidised and disaggregated on a sample shaker using 100ml 3% hydrogen peroxide with a drop of conc. NH_4OH. The solution was then wet sieved through a 32mm mesh. The fraction <32mm was taken for further sedimentological analysis, whereas the fraction >32mm was carefully washed out from the sieve into PE bottles using 50ml distilled H_2O, and prepared as follows. Depending on numbers of samples several Petri dishes (4.9cm diameter) were put on a horizontal base (Fig. 1). Two cover glasses were placed into each dish and the dishes filled to approx. 2/3 with a gelatine solution (0.06g of 700ml distilled water). After shaking the PE bottles containing the >32mm fraction a 1ml aliquot was pipetted onto the gelatine solution, slowly stirring with a pipette in order that the suspension would ideally be distributed evenly within the Petri dish. Petri dishes were left undisturbed for at least 2hrs to ensure even settlement of the suspended material. Subsequently, prepared filter strips were inserted into the Petri dishes with one end touching the bottom and the other end touching the base outside. Thus, due to cohesive attraction, water from the basin flowed to the base and was picked up with a pipette or absorbing paper. For this purpose, a sedimentation 'stairway' was constructed at the Alfred Wegener Institute (Zielinsky, 1993), making this preparation step much easier. In the Petri dishes only the dry cover glasses remained, with an equally dispersed >32mm fraction. These were put onto glass slides using canada balsam as mounting medium.

$$N_{spicules/g} = (0.3925\,(n_1+n_2)\,V_{H2O}\,d^2)/(V_{al}\,l^2\,M_s)$$

(where N= amount of spicules per gram of freeze dried sediment; n_1+n_2=amount of spicules counted in the preparation; V_{H2O}=volume of distilled water added to the sample; V_{al}=volume of the sample aliquote; l=length of the cover glass; M_s=weight of the freeze dried sample; d=diameter of the Petri dish).

The coefficient of quantity, in this case 0.3925, has to be newly determined depending on the diameter of each Petri dish using the following formula:

$$N=(0.5(n_1+n_2)\,V_{H2O}\,(d/2)^2\,p\,d^2)/(V_{al}l^2M_s)$$

RESULTS

LIVING SAMPLES. Over the Academician Ridge transect we sampled 38 living sponges from two species, of which 31 specimens belonged to a new species *Baikalospongia* sp. nov.1 (identified by S. Efremova, in prep.). This species is pillow shaped with a strongly porous surface and very stable consistency. Lateral surfaces are covered by a cornea-like layer protecting the sponge body from silt penetration. Size varies from 1-5cm. Colour of the upper surface is green- blue or brownish. *Baikalospongia* sp. nov.1 has spicules of a characteristic shape: both ends of the spicule have unique crown of thorns. The sponges grow on large, compressed, iron-manganese concretions which are embedded abundantly in the silts of the Academician Ridge. The spicules of this species were found in all sediment samples here.

Two sponges externally similar to *Baikalospongia* sp. nov.1, but with different spicule forms — short strongyles 170-215µm long, 15-22µm wide, with tiny spines diverging on all sides — may be a subspecies of *Baikalospongia bacilifera*, based on similarities in their skeletal forms.

Also interesting is the find of 5 specimens of soft, friable, brown-blue sponges, 170-215µm long, 15-22µm wide, with round oscules and unattached to any substratum. In skeletal structure and spicule morphology this sponge is similar to a variety of *B. intermedia* (Dyb.) described by Rezvoy (1936) as *morpha profundalis*. Rezvoy noted that this variety differs from*B. intermedia* s.s. in its spicule size (330-470µm long, 20-25µm wide), spicule morphology (consisting of slightly curved strongyles covered with small spines, with a dense accumulation of small pointed spines at the rounded (basal) end), and possession of weak skeletal structure (with an irregular net-like reticulation of spicules bonded at their ends by collagen). This species is previously known only

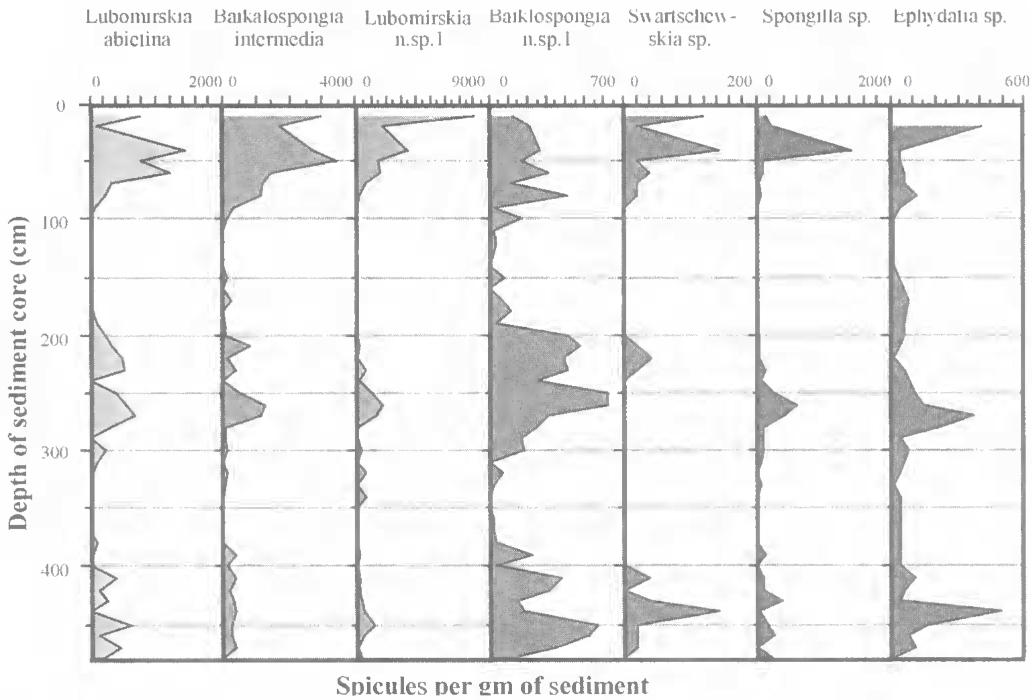

FIG. 2. Distribution of sponge spicules in sediments collected from the gravity core STX3GC.

from a single specimen collected in 1932 from 890m depth.

The taxonomy used here is based on the spicule classification system of E. Weinberg which is in some details controversal among the authors (e.g. the differentiation of isolated spicules between *Ephydatia* and *Spongilla*). However, we still consider the spicular signals sufficiently distinct to establish the specific ecological response among the fresh water sponges, Lubomirskiidae and Spongillidae.

SUBRECENT AND FOSSIL SAMPLE MATERIAL. Analysis of slides preparations of sediment sample revealed 7 different species of Lubomirskiidae. Analysis and description of the latter are in progress. The most prevalent and widely distributed spicules found in surface sediment samples came from *Baikalospongia intermedia*, followed by *Lubomirskia abietina*, *Baikalospongia* sp. nov.1, *Baikalospongia* sp. nov.2, *Baikalospongia* sp. nov.3 and Lubomirskia gen. et sp. nov., whereas spicules of *Swartschewskia* sp. were relatively rare.

The concentration of the spicules in surface sediment samples was inversely correlated with water depth, showing a general decrease in abundance of spicules in sediments as water depth increased (Fig. 5).

TABLE 1. Distribution of sponge species in the central part of Lake Baikal.

Sponges species	Ushkany Is	Akadem -ician Ridge	Surfacial ground	STX3GC
1. *Baikalispongia bacillifera*	-	-	-	-
2. *B. intermedia*	+	+	+	+
3. *B.interm.* m. *profund.*	+	+	+	+
4. *B.bacillifera*, ssp. 1	+	+	+	+
5. *Baikalispongia* nsp. 1	+	+	+	+
6. *Baikalispongia* nsp. 2	+	+	+	+
7. *Baikalispongia* nsp 3	+	+	+	+
8. *Baikalispongia* nsp. 4	+	+	+	+
9. *Lubomirskia abietina*	+	+	+	+
10. *Lubomirskia* nsp. 1	+	+	+	+
11. *Swartschewskia* sp.	+	+	+	+
12. Lubomirskiidae n. G. n. sp.	-	-	-	-
13. *Spongilla* sp.	+	+	+	+
14. *Ephydatia*	+	+	+	+
15. New spicule 1	-	-	-	+
16. New spicule 2	-	-	-	+

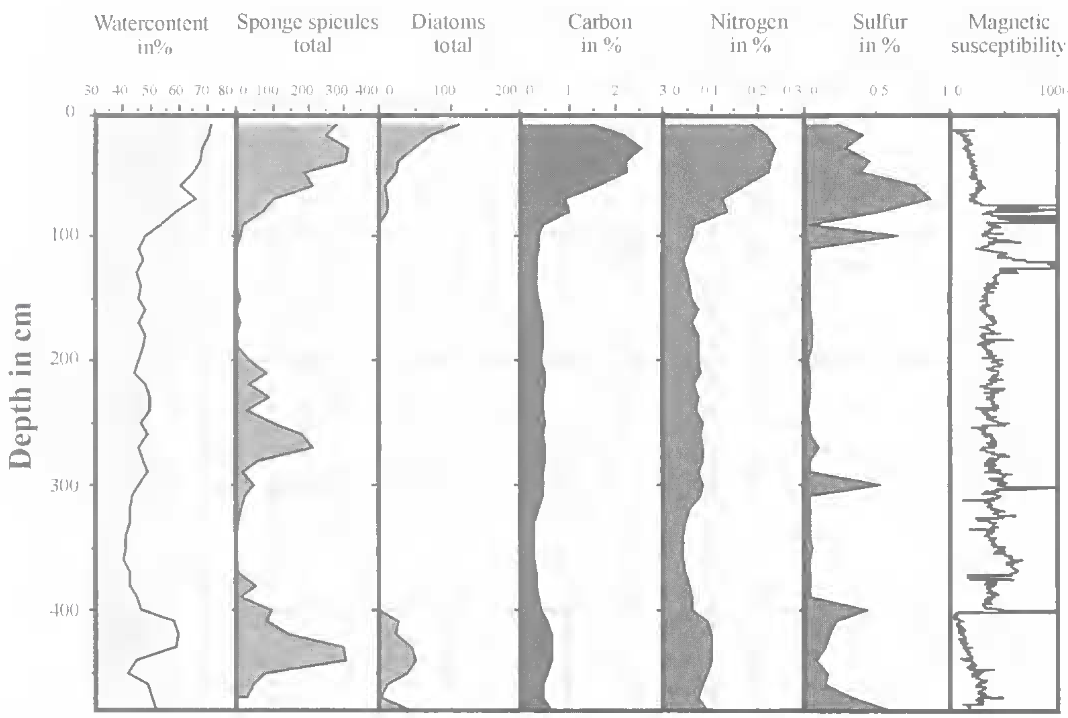

FIG. 3. Sediment parameters of the gravity core STX3GC.

Analysis of the gravity core STX3GC revealed four genera of Lubomirskiidae in nine species, in addition to mega- and microscleres of Spongillidae *Spongilla* sp. and only megascleres of *Ephydatia* sp. (Fig.3, Table 1). We also found spicules that could not be attributed to any known living species. Some of these were extraordinarily long (360-700µm), relatively thin (12-16µm) and with small spines spread over the whole rhabd. Others had a smooth surface and a relatively thick rhabd with a length of 225-280µm and width of 24-40µm, and small spines found only on the ends.

The abundance of sponge spicules throughout the core indicates that cyclic environmental changes had taken place between these sedimentary strata as indicated by maximum and minimum spicule concentrations. The first maximum concentration showed up in Holocene sediments, down to a depth of about 40cm. It is dominated by *Baikalospongia intermedia*, as for the subrecent surface sediment samples, and *Lubomirskia abietina*. The second maximum concentration commenced at a sediment depth of 200cm and ended at 300cm. This has to be classified as the Karginsk interstadial, and is indicated by the presence of spicules of *Baikalospongia* sp. nov. 1. The intervals, which according to diatom stratigraphy (Grachev et al., 1997) can be classified as glacials and stadials, are characterised by distinctly low spicule diversity and total spicule concentration, perhaps reflecting low species diversity and abundance during these periods. Spicules of *Swartschewskia* sp. and *Spongilla* sp. disappear completely during these intervals.

DISCUSSION

The presence of both living sponges and their spicules in subrecent sediments on the Academician Ridge suggest that sponge spicules are an autochtonous element of these sediments. This opinion is confirmed by the presence of large numbers of spicules from *Baikalospongia* sp. nov.1 in the surface samples of ST14, located near living populations.

Sponges have adapted to life on a loose silty substrata in different ways. Firstly, they may live without a fixed anchorage to the bottom, as seen in *Baikalospongia intermedia* morpha *profundalis* living on the Academician Ridge. Rezvoi (1936) described similar examples of sponges living on loose substrata without any fixed anchorage. Secondly, sponges may live on

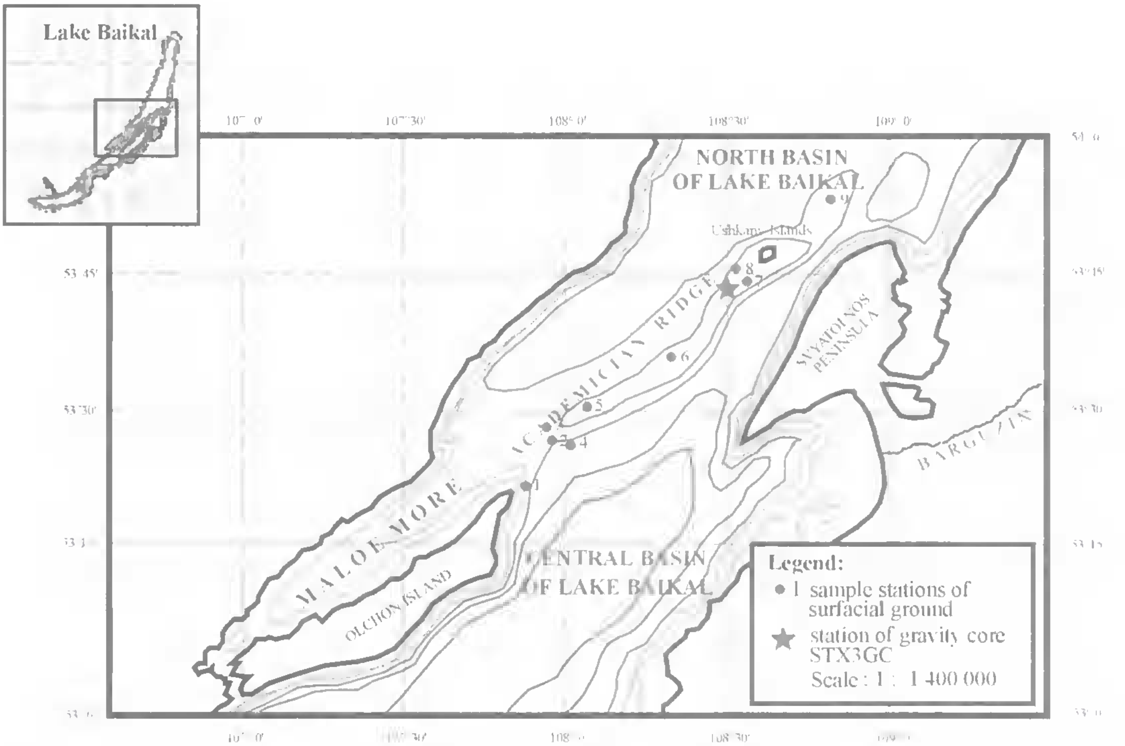

FIG. 4. Map of the study locality in Lake Baikal indicating station sites for surface sediments and gravity core samples.

ferro-manganese crusts in which they build up a horny layer for protection against sedimentation in the muddy environment. This strategy is seen in *Bakalospongia* n. sp 1 and *Baikalospongia bacillifera*. Thirdly, sponges may grow on other sponges, using their horny layer as a substrate. An example of this commensalism was seen in a specimen of *Baikalospongia* sp. nov. 1 covered by two smaller individuals of the same species living on its horny external layer, collected by our expedition to the Bolshye Koty area in 1998, at a water depth of 100m. The expedition of the Irkutsk State University found a similar specimen at Academician Ridge, kindly provided to us by Dr. V. Takhteev. In this case it is also possible that the two smaller individuals may be buds of the larger 'parent' sponge.

Spicules were found in both subrecent and fossil sediment samples, including those of species living today in near shore areas and shallow waters of Lake Baikal. These mainly concern Spongillidae but also some representatives of *Lubomirskia*. The Recent spectra of species in the area of the S part of Bolshye Ushkany I. is generally comparable with the spectra found in the gravity core STX3GC (see Table 1). Assuming that prevailing wind directions have changed from E to NE, these sponge spicules are probably allochthoneous material brought in from the Barguzin Bay and Ushkany Is. Even during periods of more prevalent SW winds the cyclonic centre remains above the Ushkany Is. Thus, sediment material is also transported from near shore areas into central parts of Lake Baikal. Based on these facts, we consider that a part of the spicules found by us from the Academician Ridge are allochtonous whereas the others are autochtonous in origin.

In general sponge spicules are not regularly distributed within sediments, showing distinctly different patterns during colder and warmer periods of the Lake. Maximum concentrations of spicules occur in the Holocene and late Pleistocene (Figs 3-4). During this peak there is also a maximum concentration of diatoms present in sediments, demonstrating that it was a period of longer lasting warm weather and high bioproductivity. In contrast, sediments laid down during the long lasting Sartan stadial (latest Pleistocene), a relatively cool period, show

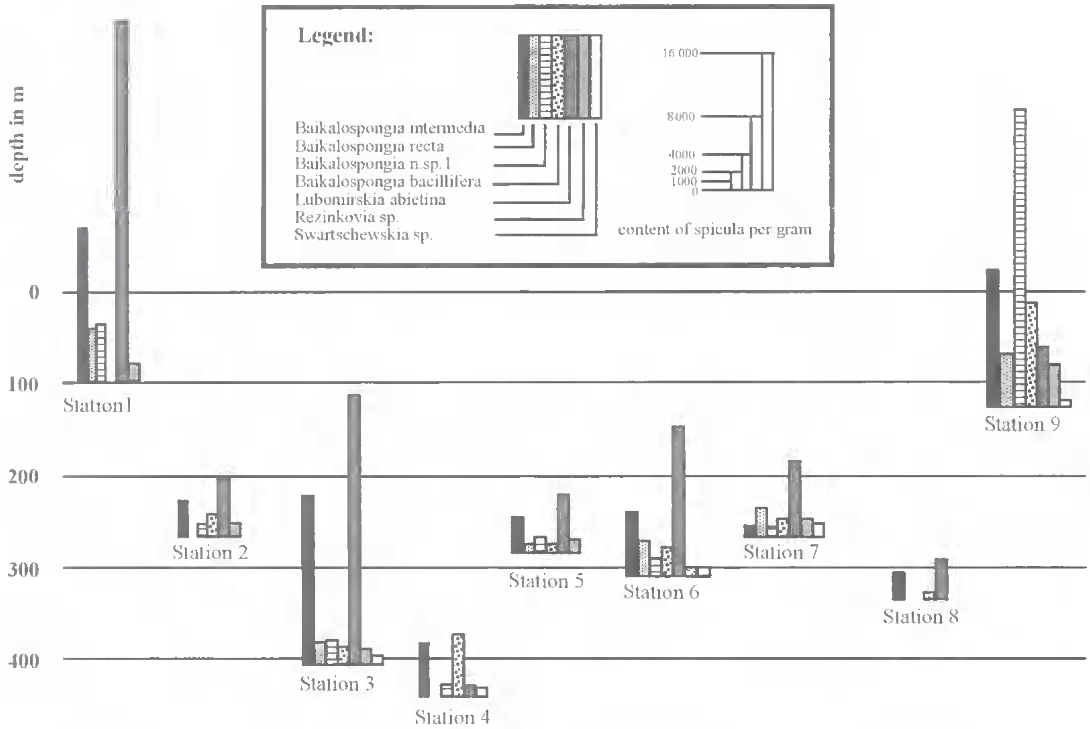

FIG. 5. Relative composition of sponge spicules in subrecent sediments in relation to water depth.

variable concentrations of diatoms ranging from very low to virtually absent (Fig. 4), whereas sponge spicules are present, and spicule abundance of *Baikalospongia* sp. nov. 1 is at a maximum, during this period. It is possible that this deep water species can better survive or adapt to changing environmental conditions due to particular nutrient regimes and possession of symbionts, because its growth is not strongly dependent on the availability of organic nutrient supplies. A change in water chemistry, resulting in dissolution of diatom frustules during colder climates, as hypothesised by some scientists (e.g. Grachev et al., 1997), seem unlikely given that the biogenic silica of sponge spicules and diatoms is identical. If this were so then it would be expected that during a change in pH conditions there would be dissolution of both sponge spicules and diatom frustules. A better explanation proposed by Back & Strecker (1998) is that during colder climates, and largely during glacial activity, high amounts of suspended material were transported into the Lake largely reducing light transmission in surface waters. This could have led to a distinct decrease in the diatom population, whereas its effect on the sponge fauna, if any, would at worst have led to a change in their symbiont relationships with little or no impact on their general living conditions.

Not all sponge species were present consistently over time. Spicules of *Swartschewskia* sp. 1 and *Spongilla* sp. occur only in the concentration maxima of the Holocene and the Karginsk interstadial. These species are typical representatives of the littoral environment, and are obviously more prone to environmental changes than deeper water species. These species are potentially useful palaeomarkers as indicators of relatively warm periods.

The occurrence of unidentified spicules in sediments, so far are unknown to any species, suggest that the Lake Baikal fauna may contain undescribed species of sponges, particularly in the endemic family Lubomirskiidae. Of special interest in this regard is our further investigations of deep drilling cores BDP-96 from the Academician Ridge, which contains nearly 5m.y. of sedimentary records. Thus, even single spicules of new species can provide information about the evolution of Lubomirskidae as well as their probable spongillid ancestry.

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